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GEOPHYSICS

Variations in the Duration of the Navigation Period along the Northern Sea Route in the 21st Century Based on Simulations with an Ensemble of Climatic Models: Bayesian Estimates

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Abstract—As global warming continues in the 21st century, one can expect a significant increase in the duration of the navigation period along the Northern Sea Route. In this study we found that, according to the representative concentration pathways 4.5 and 8.5 scenarios of the anthropogenic impact, the expected duration of the navigation period along the Northern Sea Route in the middle of the 21st century would be two to three months and three to six months by the end of the century.

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According to model estimates, we can expect a significant increase in the duration of the navigation period (NPD) along the Northern Sea Route (NSR) as global warming continues in the 21st century [1–6]. It is worth noting that the modern climatic models are characterized by significant uncertainty of the sensitivity of sea ice characteristics in the Arctic Ocean to the climate changes both in the numerical experiments of climate reproduction in the 20th century and in the estimates of climatic changes in the 21st century [2–4, 6–8]. Hence, we have to use the methods of analysis, which take into account the uncertainty of the results of numerical simulations using climatic models (and also uncertainties of the data of observations) to obtain more reliable estimates of the variations in the NPD along the NSR expected in the 21st century. For example, the authors of [2, 3] selected models from the ensemble of climatic models that realistically reproduce not only the current NPD along the NSR compared with the data of observations, but also the rate of its variation in recent decades. Adequate reproduction of standard deviations of the interannual variations in the NPD was required in [4, 5]. This is related to the description of the natural variability in the climatic models, which is not always satisfactory.

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The goal of this work is to analyze the variations in the NPD along the NSR based on simulations using the climatic models of the Coupled Models Intercomparison Project, phase 5 (CMIP5) [7] and ensemble and Bayesian averaging [9–11]. It was found that, if the Representative Concentration Pathways (RCP) scenarios 4.5 and 8.5 of the anthropogenic impact are used, the expected NPD along the NSR would be two to three months in the middle of the 21st century and three to six months by the end of the century. However, the results of the work are characterized by high scattering between individual climatic models.

Variations in the surface temperature at the Arctic latitudes in the 20th century notably (by approximately a factor of two) exceeded the global mean variations [7]. In recent decades, warming has been accompanied by a rapid decrease in the area of the sea ice in the Arctic. The annual mean volume of the Arctic sea ice decreased from 1979 to 2012 at a rate of approximately 4% over one decade [7]. In the case of continuation of modern climate warming, it is possible that in the 21st century already a transition to a completely ice free Arctic basin could occur, in particular, in the warm seasons [7, 8].

In our work we used model simulations over 1979–2100 using the CMIP5 models. The selection of the initial year for the period analyzed is related to the availability of satellite data and the sea ice concentration in the Arctic Ocean from 1979. We used the results of the "historical" scenario for the numerical simulations in 1979–2005, while for 2006–2100, we used the simulations with the ensemble of the CMIP5 climatic models and the scenarios of the anthropogenic and natural impacts of the RCP family. We also used the results of simulations using the moderate